Project Report

May 2025

Baseline assessment of the Pavana catchment for the implementation of watershed development and sustainable water resources management

Prepared For :

Wildlife Conservation Trust
Mumbai

Prepared By :

Society for Promoting Participative Ecosystem Management (SOPPECOM), Pune

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Executive Summary

This baseline assessment presents a comprehensive overview of the Pavana catchment—situated in the upper Western Ghats—as a foundation for designing context-specific watershed development and sustainable water resource management strategies. The study integrates physical, ecological, hydrological, and socio-economic insights to inform interventions that are both technically sound and socially inclusive.

The Pavana catchment is characterized by steep slopes, shallow basaltic soils, and a high annual rainfall of 2500–3000 mm. Despite this, the region faces acute seasonal water scarcity due to rapid surface runoff, limited groundwater storage, and minimal surface water retention structures. The area's aquifers consist of thin weathered basalt layers with low yield and seasonal recharge dependency. Currently, water consumption is estimated at 1.5 MCM, while the surplus harvestable runoff is 13.1 MCM—but with a storage potential of only 0.3 MCM. Land use is dominated by forests (43.6%) and grasslands (26.4%), with only 10.7% under agriculture. This points to a natural advantage for forest-based and livestock-oriented livelihoods rather than intensive crop production. Over the past two decades, tourism has emerged as a major driver of economic change in the region, influencing land use patterns, increasing water demand (an estimated additional 1.2 MCM annually), and shifting occupational structures away from agriculture and toward services and wage labor.

The catchment hosts diverse social groups, including tribal communities (Thakars and Katkaris), smallholder farmers, and landless households, many of whom depend on wage labor and seasonal collection of non-timber forest products (NTFPs) for sustenance. Tourism has brought both opportunities and stress, including greater employment but also mounting pressure on land and water resources.

This report recommends a watershed-based development approach grounded in ecological sustainability, land capability, and equitable resource use. It prioritizes soil and water conservation, vegetative regeneration, dryland horticulture, and livestock-based systems. Interventions must move beyond conventional runoff harvesting or distribution of assets and instead promote regenerative, risk-reducing systems that align with the region's topography, resource endowment, and evolving socio-economic context.

Ultimately, the goal is to enhance the resilience of local communities by improving water availability, promoting green food systems, and supporting sustainable livelihoods through integrated watershed management.

Chapter 1: Introduction

Context

The Northern Western Ghats (NWGs), globally recognised as a biodiversity hotspot, feature rugged terrain, high rainfall variability, and a mosaic of forested, agricultural, and increasingly urbanised landscapes. This region is pivotal in maintaining ecological balance and supporting diverse communities' livelihoods. However, escalating anthropogenic pressures, deforestation, land-use changes, and erratic monsoons have led to natural resource degradation, heightened vulnerability to soil erosion, water scarcity, and biodiversity loss.

Located within the NWGs, the catchment area of Pavana dam extends from the high elevations of the Western Ghats crestline eastward. Situated in Maval Tehsil near the foothills of Tikona and Lohagad forts, the dam's surroundings, characterised by serene mountains, historic forts, and forested areas, have increasingly become a tourist attraction. There has also been an increasing trend of land purchase by outsiders, reshaping the region's landscape and land-use patterns towards more urban settlements, and placing significant stress on natural resources. Key threats in this fast-changing landscape include biodiversity loss, acute water scarcity, particularly in the summer season, and increased risk of landslides due to deforestation and soil erosion. Understanding the ecosystem and availability of natural resources is critical for developing strategies for sustainable management and equitable distribution. This report presents findings of a short-term assessment of the watersheds of the Pavana dam catchment area to provide insights for the implementation of watershed development towards sustainable water resources management.

This study is supported by the Wildlife Conservation Trust (WCT) as part of a broader initiative aimed at addressing critical challenges in the region, including biodiversity loss, water scarcity—particularly during the summer months—and landslides resulting from deforestation and soil erosion. While WCT is leading the overarching effort, SOPPECOM is responsible for preparing a comprehensive watershed development plan tailored to the region's specific ecological and socio-economic context.

Objectives

The main goal of this project is to develop a long-term strategy for biodiversity conservation and the sustainable management of water resources within the Pavana dam catchment. As part of this initiative, the current study focuses on conducting a preliminary situation analysis of the watershed. The key objectives of this assessment are:

- To understand the biophysical characteristics of the catchment, including micro-watershed delineation, drainage patterns, land use/land cover, and other relevant parameters.
- To estimate the current and potential water availability and use in the region.
- To identify opportunities for developing a comprehensive and context-specific watershed development plan.

Central to this effort are field surveys, stakeholder consultations, GIS-based data analysis, and the formulation of watershed management plans aimed at ensuring long-term ecological conservation and efficient resource utilisation.

Chapter 2 : Study Area

Geographical Location of Pavana Dam Catchment:

The Pavana dam, a masonry dam located in Maval Taluka, District Pune, Maharashtra, India, (Figure 2.1), has a catchment extending from 18º41’42’’N to 18º42’29” N latitude and from 73º25’08” E to 73º30’19” E longitude. It is located at a distance of 2.5 to 3.0 km from the ridge line (straight line) of the Western Ghats. Constructed on the Pavana River, a tributary of the Mula River, the dam creates the Pavana Lake, a crucial reservoir supporting irrigation, drinking water supply, and hydropower generation. Its surroundings also serve as a popular destination for recreational activities like camping and boating. The designed storage capacity of the dam is 240 MCM.

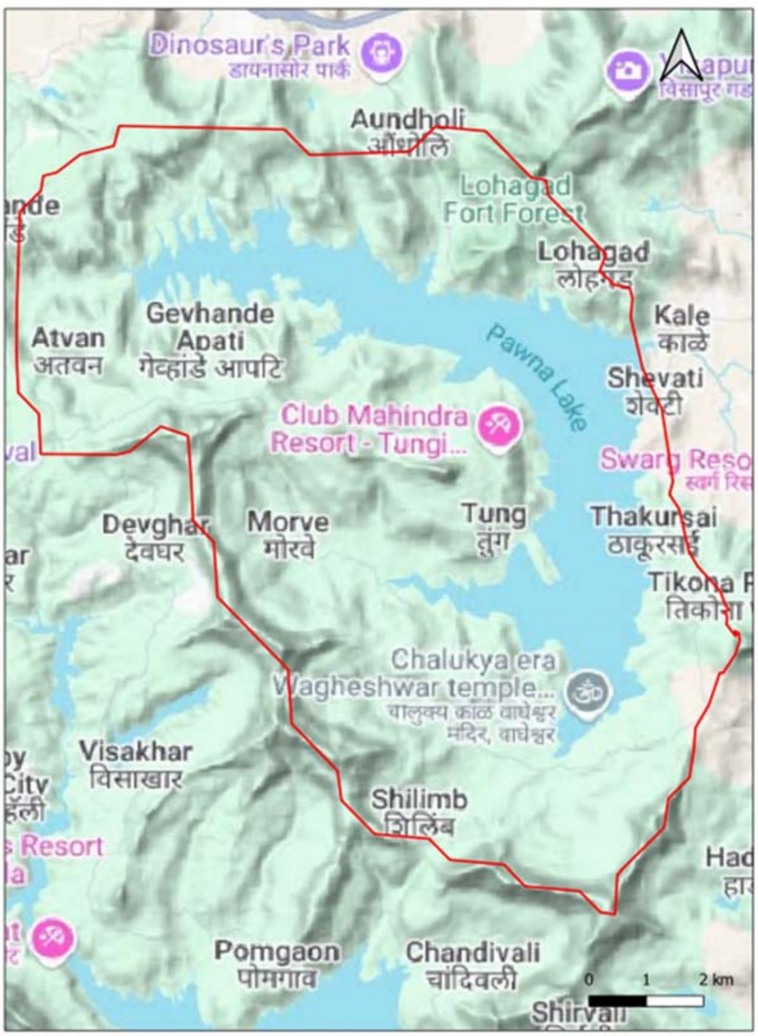

Figure 2.1: Location map of the Pavana catchment (Source: Google Maps)

Climate: Precipitation, Temperature Patterns, and Seasonality

The Pavana catchment spans approximately 115 sq.km and includes about 32 micro-watersheds. Situated near Lonavala, it experiences a subtropical climate with temperatures ranging from 20°C to 42°C. The area falls between two different isohyets - the ridge or the crest line which receives rainfall greater than 2500 mm annually, and the other is the valley portion which receives rainfall in the range of 1500-2500 mm. The drainage density of the region is approximately 2.947 km/sq km (Gole *et al*, 2018)[1], indicative of its hilly terrain and active hydrology. The region receives rainfall from May to December, with most of the rainy days falling between June to September.

Physical Features: Topography, Drainage, Geology, and Soil Types

The area is located at an elevation ranging from 588 to 1115 meters above mean sea level with a rugged topography, bordered by forts like Tung, Tikona, Lohagad, and Morgiri, and marked by steep slopes that result in high surface runoff and limited groundwater recharge. The geology comprises basaltic rock formations with shallow soils in upland areas and deeper alluvial soils in flatter zones. Soils are mostly basaltic, but with considerable sandy content. In the upper reaches, lateritic soils are found with limited water-holding capacity.

The slope map of the Pavana catchment (Figure 2.2) shows the terrain categorised into five slope classes, ranging from 0–2% (dark blue) to 30–100% (brown). A significant portion of the catchment, especially the outer region towards the ridge line, is dominated by steep slopes (15–30% in yellow and 30–100% in brown), indicating hilly terrain that is prone to runoff and soil erosion. The inner regions surrounding the reservoir show gentler slopes (2–10% in green and 10–15% in light green), making them more suitable for certain types of land use and watershed interventions. Very flat areas (0–2% in dark blue) are minimal and mostly the reservoir itself. This slope variability suggests that watershed treatment and conservation measures must be carefully tailored to the terrain, with strategies designed to suit the specific slope classes of the region.

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[1] Gole, S., Pathak, Y., Gindi, R., & Deodhar, A. (2018). *Assessment of Restoration Potential in the Catchments of Pavana, Chaskaman and Dimbhe Dams in Northern Western Ghats*. Journal of Ecological Society (35-58).

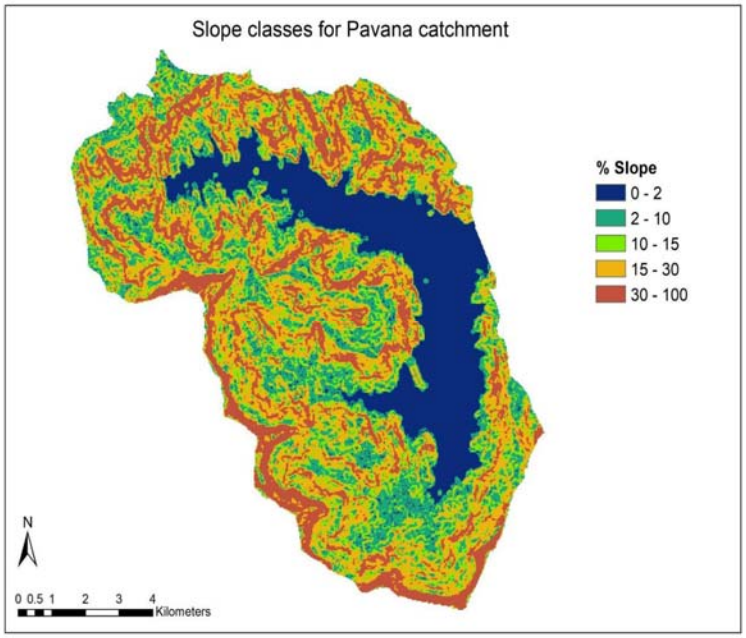

Figure 2.2: Slope classification of the Pavana catchment

The land cover classification

The land cover classification map of the Pavana catchment for the year 2021 as shown in Figure 2.2 provides a broad classification of the region's landscape, offering a basic understanding of its ecological and hydrological features. Based on ESA Global land cover data at a 10 m resolution, the classifications—including tree cover, shrubland, grassland, cropland, built-up areas, barren land, and water bodies—have been standardised for global applicability. These categories effectively emphasise the predominant land cover types within the region. Despite their generalised nature, these classifications are valuable for identifying key landscape patterns, such as extensive forest cover (43.6%), substantial water bodies (18.2%), and agricultural areas (10.7%) (see Table 2.1). They serve as an effective baseline for conducting more detailed, site-specific analyses.

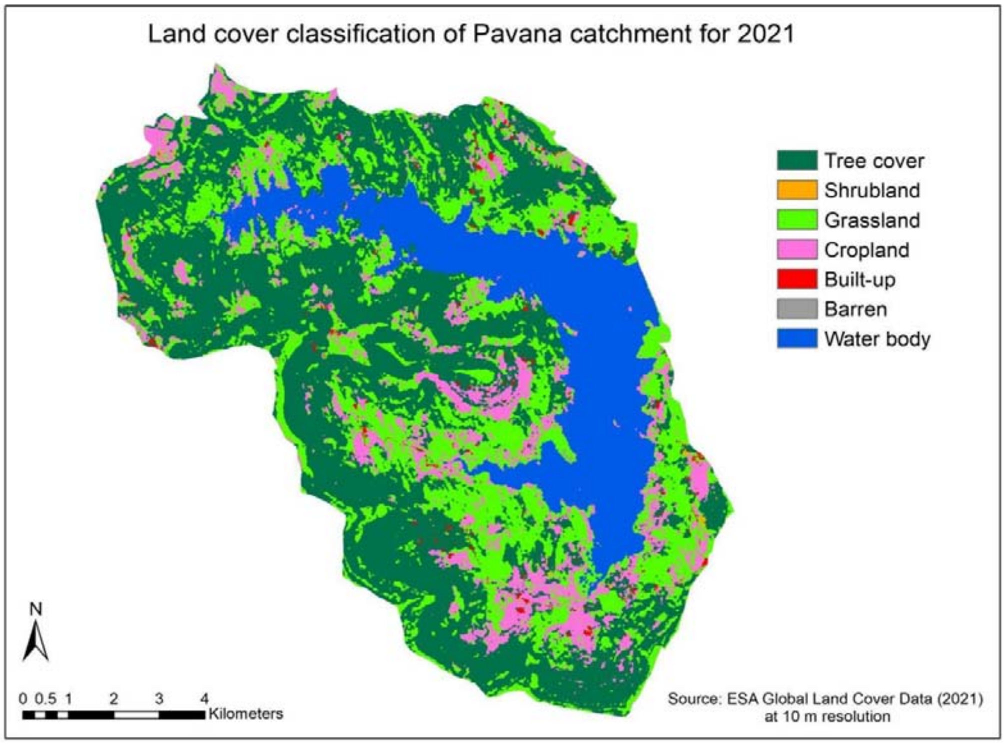

Figure 2.3: Land Cover map for Pavana catchment for the year 2021 (Source European Space Agency)

Table 2.1: Area under different land cover classes

Land cover	**Area (sq.km)**	**% Area**
Tree cover	50.2	43.6
Shrubland	0.2	0.2
Grassland	30.4	26.4
Cropland	12.3	10.7
Built-up	0.8	0.7
Barren	0.2	0.2
Water body	21.0	18.2

Socio-Economic Context Relevant to Water Resource Management

Population and Demographics

The catchment currently includes 30 villages, with a population of approximately 9,946 (as of 2021) across 1500 households. Tribal communities such as *Thakar*s and *Katkari*s are sparsely distributed.

Livelihoods Profile:

Agriculture, predominantly rainfed paddy during the Kharif season, is the mainstay for many, though limited by the terrain and water availability. Non-farm income sources, including wage labour and tourism-related activities, play a significant role. The tribals rely on fishing, agricultural labour, and other unorganised sectors for their subsistence.

Development Challenges:

Modern infrastructure development, such as road construction, has improved connectivity but caused environmental impacts like forest fragmentation and soil erosion. Tourism around Pavana Lake generates seasonal employment but brings challenges like waste management and ecological degradation.

Issues of Land Alienation

Urbanisation and tourism-driven development have intensified land alienation issues. Outsiders often acquire prime land from the local communities near tourist locations (scenic and easily accessible). Our engagement with the local community revealed that nearly 40% of the land is currently owned by individuals or entities from outside the area. This shift in land ownership has significant implications for conservation and development efforts in the watershed, particularly for community-based initiatives focused on land and water resource development and management. There is a high possibility that the enhanced or newly developed resources, such as water, will primarily benefit outsiders and commercial interests, rather than local communities and their livelihoods. Such commercial development often overlooks ecological sensitivities, leading to issues like water scarcity, pollution, and growing socio-economic disparities.

Chapter 3 : Methodology

The watershed assessment study adopted an integrated methodological approach to capture the ecological, hydrological, and socio-economic dimensions of the landscape. The key components of the methods used included **field surveys**, which helped document existing cropping and land use patterns and water resources; **stakeholder consultations** through Focus Group Discussions (FGDs) and interviews, which provided valuable local insights on resource use, challenges, and community priorities. We also carried out **data analysis using Geographic Information Systems (GIS)** to spatially map watershed features, analyse terrain and land cover, and identify critical intervention areas. Based on the findings, a **draft watershed management plan** has been developed, along with **suggestions to ensure long-term conservation and efficient resource utilisation**, with a focus on ecological restoration, improved water management, and sustainable livelihood opportunities.

Secondary Data

The secondary data sources included Census 2001 and 2011 for analyzing population trends. A Digital Elevation Model—SRTM 1 arc-second raster (Source: USGS Earth Explorer)—was used for watershed delineation, stream mapping, and terrain analysis. ESA Global Land Cover data at 10 m resolution (Source: European Space Agency) supported the mapping of land use and land cover within the watershed. Additionally, 10 years of daily rainfall data (2013–2023) from the Kale Colony and Lonavla rain gauge stations in Maval Taluka were obtained from *Maharain*, a Government of Maharashtra portal. This data was analyzed to calculate the average annual rainfall in the region.

Watershed Delineation and Drainage Mapping

Watershed delineation was done using QGIS, an open-source GIS software available (version 3.18 Zurich). The data set required for the watershed delineation was Digital Elevation Model for the region.

Steps taken for watershed delineation

- Download the STRM layer for the region from USGS Earth Explorer (https://earthexplorer.usgs.gov/)

- Within QGIS this raster layer was reprojected in the required coordinate system (UTM 43 N)
- The SAGA tools within QGIS were then used to delineate catchments, micro watershed boundaries, and streams.

Water Availability Estimation

The equation used for the estimation of the water availability:

Rainfall Volume = Evapotranspiration + Groundwater storage+ Runoff Volume + Local Surface storage

Assumptions

- The rainfall was taken as an average between the two isohyets that is greater than 2500 mm at the Crestline and between 1500 to 2500 mm at the Pavana dam site. The rainfall analysis has been detailed in the next section.
- Based on the land use classes, the evapotranspiration was calculated. The rates of evapotranspiration for this region are as shown below:
    - From the area under Tree cover, 35% of the total precipitation. The maximum ET contribution from the Western Ghats is in the range of 25 to 40%, and only during the rainfall deficit years, it can go up to 50%, according to Paul et al (2018)[2]. Since for the water availability, average rainfall has been assumed, and the ET has been assumed to be 35%
    - From the area under Non-agriculture use, including built-up area, 20% of the total precipitation.
    - From Fallow land - 20% of the total precipitation
- From Cropland - 30 % of the total precipitation. This assumption has been based on the fact that in this region, there is predominantly a single crop that is rainfed, and the total irrigated area is also less than 1% of the total land under agriculture.

[2] Paul, S., Ghosh, S., Rajendran, K., & Murtugudde, R. (2018). Moisture supply from the Western Ghats forests to water deficit east coast of India. *Geophysical Research Letters*, *45*(9), 4337-4344. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL078198#:~:text=The%20mountainous%20western%20coast%20of,reach%2050%25%20during%20dry%20periods

- Groundwater recharge to shallow aquifers from the impounding of water in check dams is considered to be 10% of the total precipitation[3].

Hydrological Assessment in the catchment

A hydrological assessment was carried out in the catchment to evaluate existing watershed interventions, including water and soil conservation structures, and to identify the potential for implementing additional measures. The assessment began with a desktop analysis to develop a preliminary understanding of the watersheds. This was followed by intensive field surveys and transect walks to gain a comprehensive on-ground perspective of watershed conditions and opportunities.

Desktop assessment:

The following activities were carried out under the desktop assessment as below:

1. Mapping of all the water storage structures using Google Earth and GSDA groundwater recharge priority maps
2. Downloading the GSDA recharge priority maps.
3. Overlaying the existing water structures on the recharge potential maps to understand the overall situation in relation to water conservation and storage structures in the catchment
4. A baseline map for carrying out the field assessment

Field survey:

For the field survey, structures in Ajivali, Shilimb, Morave, Chavsar and Tung village were visited, along with the private and public land to study the land use pattern and agricultural practices. All the Cement Nala Bunds/ KT weirs were assessed through transect walk along the streams. During the transect walk an assessment of the overall observations related stream cross section, morphology and geology were also noted to assess if there were suitable locations for construction of new check dams/ KT weirs. Only the farm ponds that were not within any fenced private property could be assessed. Most of the Earthen Nalla Bunds (ENBs) were covered, except those in remote forest areas.

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[3] Report on Groundwater Resource Estimation Committee (2009). Ministry of Water Resources. Retrieved from [CGWB - Publications and Media Warehouse]

Chapter 4 : Watershed Assessment

Understanding the hydrological dynamics of a watershed is essential for effective water resource planning and management. This assessment focuses on a comprehensive analysis of the watershed through three key components: watershed delineation, rainfall analysis, and water availability evaluation. Delineating the watershed boundary helps define the area contributing to surface runoff and provides a spatial framework for further analysis. Rainfall data is analysed to understand seasonal and annual precipitation patterns, which are critical for estimating water input into the system. Finally, the study assesses water availability by examining surface and groundwater resources for sustainable watershed development and management.

Watershed delineation

Figure 4.1 shows the micro watershed map of the study area along with the drainage channels. There are 32 micro watersheds in the catchment contributing to a total area of 9247 ha, as summarised in Table 4.1. According to the Land Use Land Cover (LULC) map as shown in Figure 2.2, the total area of the catchment is 9410 ha. This gives a difference of about 163 ha (error of 2%), which can be attributed to the datasets from different sources and used by GIS software to compute areas. Hence, this is within the acceptable limits.

The stream order of the drainage lines is from 4th order to 6th order. Only the major streams within the micro watersheds were considered and presented, and discussed in this report.

Table 4.1: Microwatersheds in the Pavana catchment

Sr no.	Name	Area in Ha	Sr no.	Name	Area in Ha
1	MW1	493	17	MW17	23
2	MW2	259	18	MW18	41
3	MW3	462	19	MW19	33
4	MW4	236	20	MW20	71
5	MW5	261	21	MW21	93
6	MW6	490	22	MW22	153
7	MW7	208	23	MW23	127
8	MW8	119	24	MW24	152
9	MW9	31	25	MW25	148
10	MW10	33	26	MW26	205
11	MW11	13	27	MW27	713
12	MW12	14	28	MW28	2064
13	MW13	515	29	MW29	493
14	MW14	115	30	MW30	379
15	MW15	17	31	MW31	459
16	MW16	17	32	MW32	811

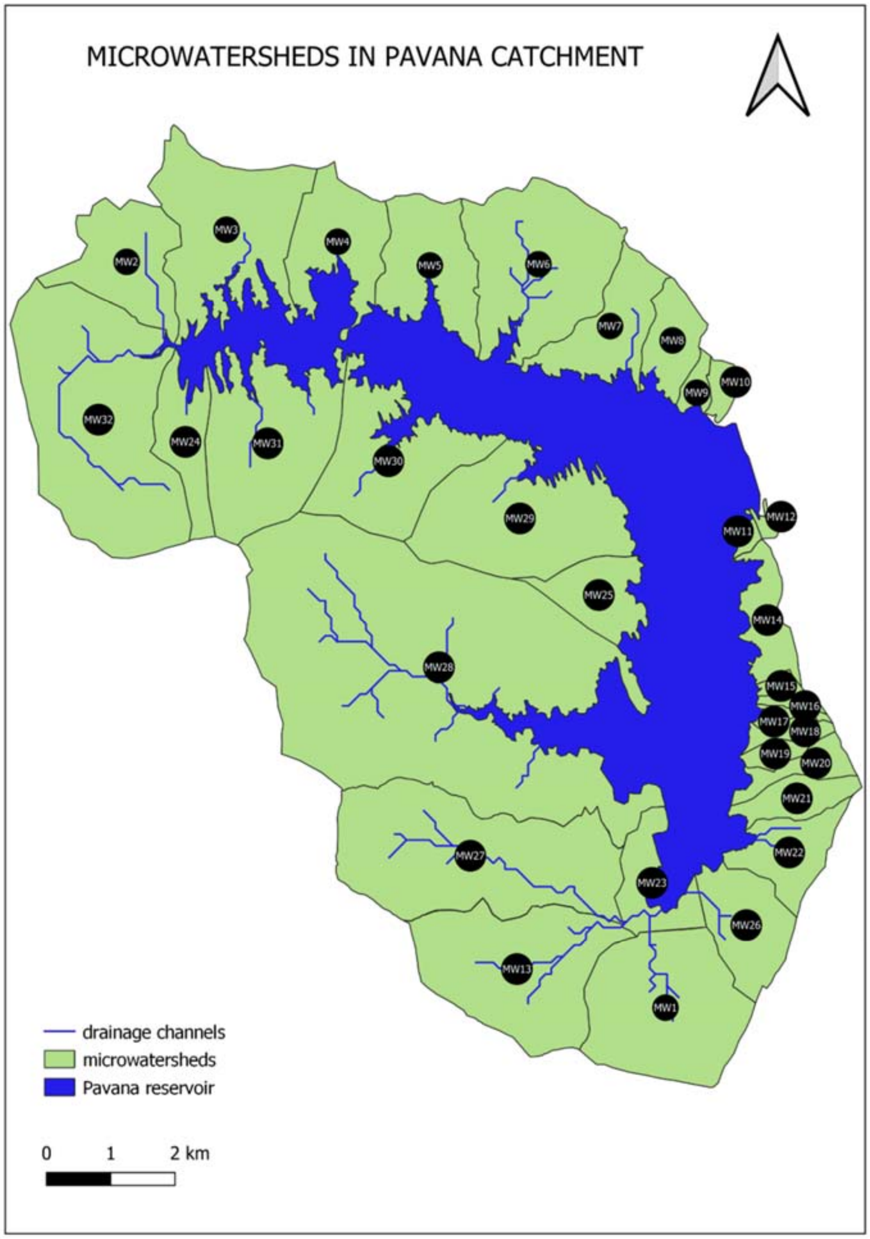

Figure 4.1: Microwatersheds in the Pavana catchment

Rainfall Analysis

The catchment spans two distinct isohyets. The area near the crestline receives over 2500 mm of annual rainfall, while the region from the crestline down to the dam site falls within the 1500–2500 mm isohyet. To estimate rainfall near the crestline, the closest available division station was Lonavla. Daily rainfall data from May to December for the years 2013–2023 were used to calculate the average rainfall, as summarised in Table 4.2. For the lower isohyet range, Kale Colony was identified as the nearest division station. Rainfall data from this station, covering the same period (May to December, 2013–2023), was similarly analysed and is presented in Table 4.3.

Table 4.2: ***Rainfall data for Lonavla division circle (in mm, rounded off)***

	2023	**2022**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**
May	0	0	70	8	0	0.5	0	0	7	0	0
June	372	67	598	373	436	320	1266	224	343	112	1533
July	1950	1659	1471	576	2083	2506	2304	1823	1124	2345	2370
August	499	1453	356	1683	1469	1369	1319	1709	452	1259	936
September	460	760	660	231	898	215	302	720	300	701	250
October	76	340	107	165	169	32	78	76	126	107	93
November	22	0	46	0	6	65	0	0	56	10	0
December	0	0	48	5	0	0	0	0	0	10	0
Total	**3379**	**4279**	**3356**	**3041**	**5062**	**4508**	**5269**	**4552**	**2408**	**4544**	**5182**
Average rainfall		**4143 mm**									

Table 4.3: Rainfall data for Kale colony ***(in mm, rounded off)***

	2023	**2022**	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**
May	0	0	54	20	0	0	0	13	2	0	0
June	310	90	388	248	259	316	515	127	472	21	1078
July	771	1215	968	254	1205	1766	1532	1007	625	1207	412
August	260	534	195	970	953	903	903	893	275	637	479
September	314	341	344	156	549	161	225	279	127	342	332
October	101	130	65	162	122	66	141	38	185	92	39
November	44	0	49	0	14	19	0	0	71	41	0

December	1	1	61	6	1	0	0	0	0	19	0
Total	**1800**	**2312**	**2123**	**1814**	**3104**	**3231**	**3316**	**2357**	**1757**	**2359**	**2339**
Average rainfall		**2410 mm**									

Therefore, for the catchment, the average of the two stations was considered. The average rainfall of the two stations is **3277 mm**.

Water Availability

The exercise to estimate water availability aims to assess the total water resources in the catchment. The total catchment area is based on the LULC map derived from the European Space Agency dataset for the year 2021, which indicates that the catchment covers 9410 ha, and the Pavana reservoir spans 2100 ha. Therefore, rainfall over the reservoir is considered separately. The overall water availability is summarized in Table 4.4. The total rainfall volume is calculated for both the catchment and the reservoir. From this, evapotranspiration losses are subtracted. According to the Central Water Commission Guidelines (CWGB), groundwater recharge from rainfall is estimated at 10%. The sum of evapotranspiration losses and groundwater recharge is deducted from the total rainfall volume to estimate surface runoff. Most of this runoff flows into the Pavana reservoir. The reservoir's total storage capacity at Full Reservoir Level is 240 MCM. Subtracting this storage capacity from the total volume of water entering the reservoir (runoff + rainfall over the dam) gives the excess runoff. It is assumed that about 20% of the excess runoff should be allocated as environmental flows, to remain in the river to meet ecosystem needs.

Table 4.4: Water Availability for the Pavana Catchment

	Rainfall Volume			
a)	Average rainfall in the catchment (R)	3,277	mm	
b)	Area of the catchment (Ac)	9,410	ha	
c)	Total volume of rainfall over the catchment (R x Ac) or (R X Ac)	308.4	MCM	
d)	Area of the Pavana reservoir (Ar)	2,100	ha	

e)	Total volume of rainfall over reservoir (R x Ar)	68.8	MCM	
f)	Total volume of rainfall (c+e)	377.2	MCM	
	Evapotranspiration (ET)			
		Area (ha)	**ET (% rainfall)**	**Total Volume (MCM)**
i)	Tree cover	5,020	35	57.6
ii)	Scrubland	20	20	0.1
iii)	Grassland	3,040	20	19.9
iv)	Cropland	1,230	30	12.1
v)	Built up (settlements, roads, etc)	80	5	0.1
vi)	Barren	20	10	0.1
g)	Total ET water requirement			89.9
h)	Groundwater recharge and impoundment in local check dams		10% of rainfall	30.8
i)	Total runoff from the catchment (c-(h+i))			187.2
j)	Total water available at Pavana reservoir from surface runoff + rainfall over the reservoir (i+e)			256.4
k)	Gross storage capacity of Pavana reservoir			240.0
l)	Excess runoff generated (k-l)			16.4
m)	Environmental flow requirement		20% of excess runoff	3.3
n)	**Surplus volume of water that can be harvested through watershed development activities (for drinking water, domestic use, agriculture, livestock, and other livelihoods)**			**13.1**

The surplus volume of **13.1 MCM** represents the additional water available for watershed development activities after accounting for evapotranspiration, groundwater recharge, and environmental flows. This water can support the local economy, enhance livelihoods, improve water security, and promote sustainable development. Strategic management of this surplus will address challenges in drinking water access, agriculture, livestock management, and community resilience.

Chapter 5 : Hydrological Assessment

A hydrological assessment is essential for understanding the dynamics of water resources within a landscape and for developing effective water management strategies. This study focuses on examining existing water conservation and management interventions, such as check dams and farm ponds, to understand their effectiveness and impact. The study also includes an assessment of hydrological potential to identify areas suitable for future interventions, aiming to enhance water retention, groundwater recharge, and overall resilience of the watershed system.

Field Observations of existing interventions:

Cement Nala Bunds/ KT weirs:

The transect walk along the streams revealed that most of the stream bed is compact basalt and therefore most of the Cement Nala Bunds (CNB) on the streams do not act like water recharge structures to nearby wells, but more like storage structures. These are mostly Kolhapur Type (KT) weir bunds. Some of them have gates, while most of the gates have got washed away because of very high runoffs (Please see pictures below). The CNB structures can be repaired and retrofitted to improve storage capacity. Siltation in some areas has reduced storage capacity, but its removal can help restore it. The excavated silt can be applied to agricultural fields to enhance soil productivity and water retention. Resources for such interventions are available through the State Government's *'Gal Mukt Dharan, Gal Yukt Shivaar'* programme, as well as through support from various donor agencies.

Picture 5.1:Non-functional KT weir on one of the main streams in the catchment:

Picture 5.2: Washed away check dam on one of the streams in the Pavana catchment

Earthen Nala Bunds (ENB):

Most Earthen Nala Bunds (ENBs) in the area are constructed by farmers and typically have small catchments of up to 40 hectares. Due to the local geology and geomorphology, these structures do not retain water for long. While they offer limited direct recharge to nearby wells, their primary functions are to reduce surface runoff, minimise soil erosion, and enhance soil moisture. There is limited potential for developing larger structures like village ponds (gav talaav) in this landscape.

Farm ponds:

There are several farm ponds in the region, most of which are lined. Although this lining is not visible in the current satellite imagery due to outdated data. Field interactions with local farmers, who are also working with the Shilim Institute, confirmed that 22 ponds have been constructed and 30 more are planned, with support from the institute for both construction and lining.

However, these ponds primarily function as storage units and lack proper inlets and outlets, limiting their ability to capture surface runoff. Instead, they collect only direct rainfall and, in some cases, are used as buffer storage for borewell water—a practice that is unsustainable, especially in a groundwater-stressed context. In areas with lateritic soils, unlined ponds fail to retain water effectively, reducing their utility for farmers and offering minimal benefits for long-term water conservation.

Hydrological Potential Map:

Figure 5.1 below shows the hydrological potential map of the catchment from the point of view of existing structures, and also what is the potential for additional water augmentation in the region. The map indicates that there are red, orange and yellow areas that represent scope for groundwater recharge, and these follow a distinct contour line. All the region which is orange in colour is region with very high slopes, and hence there should not be any intervention in the form of mechanical construction in this region. The red region also has low priority for artificial recharge given the nature of the soil and the underlying geology. This is the region where there can be soil conservation, and also some loose boulder structures can be constructed in smaller streams to reduce the velocity of the flow. The yellow region is the low-lying belt near the Pavana dam, which has a moderate priority for recharge. Given the overall geology of the catchment, it has relatively less scope for groundwater recharge. There are dug wells and borewells in this region; however, the water from these wells lasts only up to February.

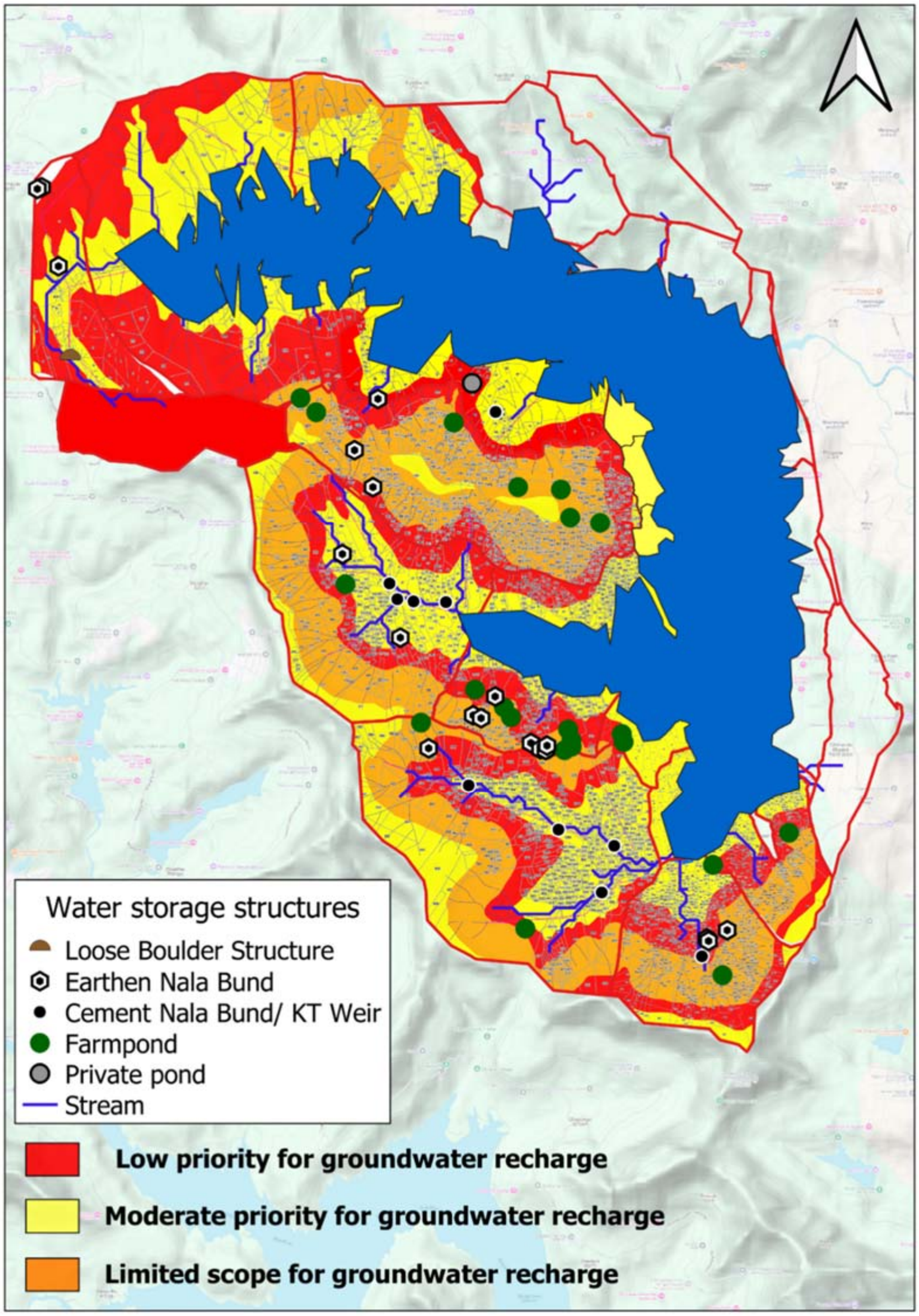

Figure 5.1: Hydrological potential map of the Pavana catchment

Estimate of the overall capacity of the existing water storage structures

We estimated the overall water storage capacity of the water harvesting or storage structures like K T weirs, check weirs, and earthen nalla bunds built in Ajivali, Javan, Shilimb, Kadav, Morave, Kolechafesar, Chavsar and Tung villages. This estimation does not include the storage of the Pavana dam. The combined storage potential of all these structures was **1,53,858 cubic meters (0.15 MCM).** This figure also accounts for existing CNBs (cement nala bunds) that are currently in poor condition and would require retrofitting and repairs to function effectively.

A total of 22 farm ponds have been recently constructed, with 30 more planned. Assuming each pond averages 25 x 25 meters in area and 4.5 meters in depth, the estimated combined storage capacity is approximately **1,40,650 cubic metres (0.14 MCM).** Adding this to the existing water harvesting structures (0.15 MCM), the total potential storage capacity in the catchment is projected to be around **0.3 MCM**.

Understanding the carrying capacity of the catchment

Since there has been a trend of change in the land use pattern in this region, with more land being sold to non-local people for building farm houses and resorts, it is necessary to understand what is the total carrying capacity of the catchment in terms of meeting these rising water demands.

It is estimated that there are about **100 residential** establishments (hotels or resorts) and about **300-500 kiosks** or restaurants of various sizes. Ignoring the footfall on weekdays, it is safe to assume that there are about **1000 residential tourists** on weekends or festive seasons and another **10000 tourists** on day visits. Assuming the residential tourists would be consuming water at 200 lpcd (similar to the average water use in Pune city) and the day tourists would be consuming water at 40 lpcd. The total water requirement for the tourist activities in the basin is about **0.3 MCM**.

Therefore, the overall water consumption in the catchment is as follows:

1. **Domestic** water consumption of the locals: **0.2 MCM**
2. Local water consumption for **agriculture**: **0.1 MCM** for irrigation (currently limited due to minimal access; about 99% of the cultivated area is rainfed)
3. Estimated water consumption by the **tourists** is **0.3 MCM**
4. Additional water consumption for **resort upkeep**, including swimming pools, lawn maintenance, and other amenities, is estimated at **0.5 MCM**

5. Water for the **construction of farm houses** (assuming 27000 litres per square foot) and about 100 such new constructions were observed in the basin each construction = 150 sq meter area) **= 0.4 MCM** (expected to increase every year)

Therefore, the current water consumption in the region is around 1.5 MCM.
The local surface storage potential is 0.3 MCM. Moreover, only probably 30% of this potential is currently realised as the existing structures require repairs and retrofitting for its full potential. This suggests that the remaining water needs are primarily met by pumping water from the Pavana dam reservoir and partially from groundwater sources.

From the estimated potential water storage in the catchment and the current consumption, it appears that there is scope for watershed development. However, the scope for building check dams is very limited. It is very important to understand that this catchment is a seasonal catchment. There are no perennial streams here. All the streams run dry in two months after the monsoon, and hence investing in extensive drainage line treatment is going to be economically impractical.

According to the preliminary water balance that was derived, the aggregate groundwater in the catchment is 30.8 MCM. However, there is a temporal and spatial constraint to this. In the regions with compact basalts, the groundwater would be percolating to deeper aquifers through the fractures and crevices. Some portion of this groundwater could also be running off into the Pavana dam. This assumption has been made from the discussion with local farmers who said that their wells run dry in the summer. The exact groundwater potential can only be determined by carrying out long-term monitoring of the water levels in the catchment. Additionally, several borewells have been drilled in the upper reaches, which poses a risk of drying out wells in the lower reaches over time, ultimately affecting water availability across the catchment. However, the lower reaches—particularly in Ajivali, Morave, and Shilimb villages—offer potential for shallow aquifer management and area treatment through measures like compartment bunding, which can help conserve soil moisture and improve groundwater recharge locally.

Though the aggregate water availability suggests that existing storage capacity is underutilised, the region faces significant constraints for implementing conventional watershed treatments. The core challenge lies in the irony of having abundant water, but only for a very short period during the monsoon. Given this hydrological pattern and the region's ecological sensitivity, any developmental interventions must be carefully planned, with a strong emphasis on assessing their long-term environmental and social impacts.

Chapter 6 : Socio-economic profile and emerging challenges

Understanding the socio-economic context of communities within a catchment is vital for designing effective and inclusive watershed development strategies. This analysis aims to capture the diverse livelihoods, resource dependencies, challenges, and priorities of local populations through Focus Group Discussions (FGDs). By engaging directly with community members—such as farmers, landless laborers, women, and youth—the study gathers qualitative insights on income sources, landholding patterns, cropping practices, access to water and other natural resources, and perceptions of existing interventions. This participatory approach ensures that local knowledge and experiences inform the planning process, and helps identify socio-economic drivers that influence resource use and management within the catchment.

The socio-hydrological landscape of the Pavana catchment area, as observed through group discussions in three representative villages—Shilimb, Tung, and Ambegaon—reveals a complex interplay of environmental challenges, changing land use, water resource constraints, and shifting livelihood strategies. These villages share several common characteristics while also reflecting unique trajectories shaped by geography, historical developments, and socio-economic transitions.

Land Use and Land Transactions

A recurring theme across all villages is the widespread sale of non-arable (locally known as *warkas* land) to outsiders over the past few decades. This trend began as early as the 1980s and 1990s, driven by the perception that such lands were unproductive. Initially sold at very low rates, much of this land has now been converted into farmhouses, tourist resorts, or commercial establishments, significantly altering the rural landscape. While this has brought some monetary gain to landowners, it has also led to a loss of local control over land and the diversion of water resources for non-agricultural uses.

Water Availability and Use

Water scarcity, particularly in the summer months, is a critical issue in all three villages. While rainfall is generally high in the region, especially in villages like Shilimb, the challenge lies in water retention and equitable distribution. Many households depend on wells and borewells for drinking and irrigation, but yields are often inadequate, especially in areas where watershed interventions have been absent or poorly maintained. The Jal Jeevan Mission is underway in all three villages to improve domestic water supply, but the infrastructure is incomplete, and some hamlets still face acute shortages. Lift irrigation from Pavana dam is practised in limited pockets but is not widespread due to cost and logistical constraints.

Agricultural Practices and Irrigation

Agriculture remains the mainstay of the local economy but is predominantly rain-fed, especially in areas with steep slopes or limited irrigation coverage. Paddy is the dominant Kharif crop, while pulses, wheat, and millets are grown in the Rabi season, where soil and water conditions allow. Only a small percentage of cultivated land has access to irrigation, and most of this is concentrated among a few farmers. The lack of dependable water sources limits the scope for crop diversification and intensification. Dairy farming is emerging as a supplementary livelihood source, especially in villages with better road access and market linkages.

Livelihoods and Migration

In addition to farming, livelihoods are sustained through a mix of dairy production, daily wage labour, fishing, and small-scale employment in nearby towns such as Lonavala and Pune. The tribal Katkari community, present in all three villages, remains particularly vulnerable, relying on seasonal labour and natural resource-based occupations like fishing. The younger population and some families have migrated for employment, although improved conditions in some villages have also prompted return migration. There is a gradual shift toward tourism-related income, such as running tent camps or transport services, especially near dam backwaters or road-accessible locations.

Soil Erosion and Environmental Concerns

All three villages experience significant soil erosion, primarily due to steep topography and intense monsoon rains. Earlier watershed interventions—such as trenching, gully plugs, and tree plantations—undertaken decades ago showed positive impacts in some areas, especially in reducing runoff and enhancing groundwater recharge. However, the current condition of these structures is poor due to a lack of maintenance. In many untreated areas, erosion continues to degrade land productivity and reduce water availability.

Watershed Development and Community Perspectives

Community members across villages voiced strong support for renewed watershed development efforts, provided they are well-designed, adapted to local geography, and implemented with quality and accountability. They emphasised the need for durable water storage structures such as well-planned weirs and lift irrigation systems from the Pavana dam. While previous projects have had limited and uneven impacts, people expressed willingness to participate actively in future interventions. There is also a growing awareness of the need for integrated soil and water conservation measures to stabilise the landscape and secure long-term water availability.

Emerging Priorities and Development Gaps

Aside from water and land-related issues, villagers highlighted the need for better infrastructure, especially access to higher education and healthcare. In the absence of local facilities, families are forced to travel long distances for basic services. Climate variability, particularly the delayed onset of monsoons in recent years, is an emerging concern, potentially impacting farming decisions and water planning. Communities are increasingly aware of these changing patterns and are calling for more adaptive and resilient approaches to rural development.

Chapter 7 : Watershed Development Strategies and Recommendations for the Pavana Catchment

Current Situation

Landscape and Hydrology of the Pavana Watershed

The catchment of the Pavana reservoir exhibits the defining geomorphological and hydrological features of the upper Western Ghats. Characterized by steep slopes, shallow soils, and a hard basaltic substratum interspersed with rocky outcrops, the terrain is dissected by a dense network of narrow gullies and first-order streams. Although the region receives high annual rainfall—ranging from 2,500 to 3,000 mm—the combination of steep gradients, shallow soil depth, and limited infiltration capacity results in rapid surface runoff and poor groundwater recharge.

As the landscape transitions into the middle reaches of the catchment, the slope gradients moderate and stream channels widen. These areas present moderate to considerable potential for rainwater harvesting and in-situ soil moisture retention, particularly where soil depth and terrain allow.

Hydrogeologically, the region is underlain by a complex aquifer system comprising multiple thin, weathered basalt layers interbedded with compact, impervious lava flows. This stratification offers limited groundwater storage. Notably, the occurrence of highly permeable zones such as amygdaloidal basalt or lateritic formations is rare. Open wells, generally 8 to 12 meters deep, are common in the lower parts of the catchment and have historically supported both domestic use and agriculture, relying primarily on seasonal recharge. In recent years, deeper borewells—often drilled to depths of 100 to 150 meters—have become more widespread, particularly for tourism and agriculture. However, high-yielding borewells remain anecdotal and are exceptions rather than the norm, reflecting the unpredictable nature of the hard rock aquifer system.

Hydrological assessments estimate that the total surplus volume of water potentially harvestable through watershed development in the catchment is approximately 13.1 million cubic meters (MCM). However, the feasible local surface storage capacity is limited to just 0.3 MCM, given the topography and geological constraints. Current water consumption across the catchment is estimated at around 1.5 MCM.

These figures suggest that while there is significant scope for improving water availability through watershed interventions, the potential for constructing new check dams is severely restricted by the rugged terrain and limited suitable sites for impoundment. Therefore, a more viable path forward lies in adopting an integrated watershed development approach—one that emphasizes decentralized water harvesting, soil and moisture conservation, groundwater recharge, and improved land use practices. Such an approach must be tailored to the region's unique topographic and hydrogeological context to ensure sustainability and equity in water access.

Emerging Socio-Economic and Environmental Challenges in the Pavana Catchment Rapid

1. Land Use Change and Tourism Expansion

The Pavana catchment has witnessed significant transformation in recent years, primarily driven by a booming tourism sector. A marked increase in land transactions—particularly of undulating or less cultivable plots—has occurred as farmers sell land to city-based buyers from Pune and Mumbai. Many of these buyers construct private farmhouses, some of which are rented out or developed into guesthouses and resorts. All 11 non-submerged, non-resettled villages in the catchment now host a range of tourism establishments, from modest food stalls to upscale resorts. While some ventures are corporate-backed, many are locally run by new entrepreneurs capitalizing on the scenic landscape and rising urban demand.

2. Changing Livelihoods and Occupations

Tourism has created local employment in hospitality, food services, cleaning, and maintenance, drawing many villagers, especially former farmers and tribal communities such as the Thakars and Katkaris, into wage labour. Employment opportunities are also sought in nearby urban and industrial areas, especially around Pune. As a result, the occupational profile of the region is shifting from agriculture to service-oriented and migrant labour. Despite these changes, 20–30% of local farmers continue farming, while an estimated 10% of landless families depend on seasonal sale of non-timber forest products (NTFPs), including *karvanda, tamarind, amla*, and *hirda*.

3. Intensifying Pressure on Water Resources

The tourism sector operates at near-full capacity during weekends and festivals, contributing significantly to water demand. As estimated earlier, tourism-induced water consumption adds approximately 1.2 million cubic meters (MCM) annually. This growing demand further strains the catchment's already limited and seasonally recharged water resources, raising concerns about long-term sustainability.

Watershed-based approach for the Pavana catchment

We propose an integrated approach to watershed development, prioritising soil and water conservation measures that are aligned with the natural resource endowments, land capability, and socio-economic priorities of the resident communities. Watershed development efforts must recognise and prioritise the needs of three core stakeholder groups:

- Small and marginal farmers who continue agricultural activities;
- Tribal communities, such as the Thakars and Katkaris, seeking wage labor and subsistence livelihoods;
- Landless families reliant on seasonal collection and trade of non-timber forest products (NTFPs).

The interventions recommended in this report aim to secure the livelihoods of these primary stakeholders while ensuring ecological sustainability and equitable access to resources.

The natural resource endowment of the Pavana catchment suggests greater suitability for forestry, grasslands, and tree-based farming systems than for conventional, seasonal agriculture. Land use and land cover data affirm this, with approximately 43.6% of the area under forest and 26.4% under grasslands, while only 10.7% is under agriculture. These patterns underscore the importance of forest- and pasture-based livelihoods over crop farming. Given these conditions, watershed development efforts in the Pavana catchment should emphasise livestock-based systems and year-round biomass production over seasonal crops. Additionally, livelihoods based on non-timber forest products (NTFPs)—such as collection, primary processing, and trade—should be recognised as key components of the local economy.

Conventional watershed development models, which often promote high-input, irrigated cropping systems modelled on Green Revolution principles, are poorly suited to hilly and tribal-dominated regions like Pavana. Instead, strategies here must be rooted in ecosystem-based management that supports biodiversity, regeneration, and sustainable use of common resources.

General Guiding principles for watershed development

As mentioned earlier, any interventions for watershed development in the Pavana catchment (and in similar terrains in upper Western Ghats) should focus on managing land use scientifically based on the land capability and natural resource endowment, instead of the otherwise popular runoff harvesting. The role of soil and water conservation should be governed by carefully selected interventions to support such scientific land use patterns.

The following guiding vision and principles should be carefully (rather, meticulously) followed in designing the watershed interventions.

1. Land Use Planning and Protection:

The primary goal of the watershed development project in the Pavana catchment is to promote a scientific and socially relevant land use pattern that aligns with the ecological realities of the upper Western Ghats. The project seeks to ensure the socio-economic well-being of the resident community, particularly the long-term inhabitants and local resource users, while avoiding further stress on water and other natural resources.

2. Conservation of Existing Biomass and Green Cover:

The watershed development approach should emphasise the conservation and ecological enhancement of existing biomass and green cover, including natural woodlands, scrublands, and thorny grazing lands. These landscapes, though often undervalued, play a critical role in supporting local biodiversity, sustaining groundwater recharge, and providing ecosystem services vital to the well-being of the resident communities. Rather than being viewed as 'wastelands' ripe for development, such areas should be preserved and ecologically enriched, where appropriate, to support native flora and fauna.

The conversion or destruction of these landscapes for water-intensive recreational infrastructure—such as artificial lawns, golf courses, or water sports amenities—should be strongly discouraged. Such developments not only compromise ecological integrity but also intensify the pressure on already stressed natural resources, especially water. The approach should align with the broader goal of ensuring sustainable and equitable resource use in the catchment.

3. Soil Conservation:

We use the term soil conservation in its scientific and integrated sense, encompassing both mechanical measures (such as earthwork for forming trenches and bunds) and vegetative strategies (involving grasses, shrubs, and trees), together with the safe disposal of excess surface runoff. These components are inherently linked and must be implemented in a holistic manner, responding sensitively to the local terrain, vegetation, and socio-ecological context.

- No Mechanical Interventions in Vegetated Upper Reaches

  Mechanical measures such as trenching, bunding, or construction of gully control structures (e.g., loose rubble plugs or gabions) should not be carried out in upper catchment areas that already have natural tree cover or substantial scrub vegetation, whether open or dense. These landscapes often possess natural resilience and protective vegetative cover that serve the purpose of erosion control. New mechanical structures should be considered only when there is clear and unavoidable evidence of active soil erosion on land surface or in gullies.

- Caution in Upper Catchments and Steep Slopes

  Extending the above principle, any form of mechanical earthwork in upper catchments—defined broadly as areas above 800 m MSL up to the ridge (approximately 1115 m MSL)—must be undertaken with utmost caution and thorough site-specific assessment. In particular, highly sloping lands (i.e., those with an average slope exceeding 30%) (see Figure 2.2) should be excluded from mechanical interventions to prevent exacerbating erosion or destabilizing the terrain.

- Soil and water conservation in areas with moderate slopes (10 to 15%)

  Various soil and water conservation measures/interventions like gully plugs, Continuous Contour Trenches (CCTs), vegetative barriers, water harvesting ponds, etc. One could also think of promoting dryland horticulture in this area.

- Interventions in gentle slopes (below 10% slopes)

  Areas below 10% slopes are generally under agriculture. The cropland is only about 10% of the total land area. Here the emphasis will be on soil and water conservation in the agriculture plots through farm bunds, soil amelioration, mixed cropping and other agronomic practices, etc. Efforts need to be made to see if the overall moisture regime can be improved and, if needed, some applied water can be made available to each family so that part of their cropland can have a second crop.

- Vegetative Measures Rooted in Regeneration, Not Plantation

  We advocate a regenerative approach to vegetation, prioritising natural regrowth over large-scale planting of saplings. This includes a gradual transition from less palatable grass species, such as *Andropogon spp.* (locally known as *Kusali gavat*)—to more palatable and locally adapted grasses such as *Pavana*, *Marvel*, *Sheda*, or *Kunda* (in the middle reaches). Achieving this requires systematic and community-led grazing management to protect regenerating species and improve pasture quality over time. Additionally, direct seeding of hardy, locally suitable tree species such as custard apple, neem, hirda, and others may be promoted to enhance biodiversity and long-term vegetative cover. The selection of species and planting strategy should emerge from meaningful dialogue with the local community, ensuring that participatory methods are applied with depth and seriousness, rather than as token gestures.

Specific Recommendations for Watershed Interventions in the Pavana Catchment

1. Soil conservation in the middle reaches

The barren lands, which are presently used for millet cultivation in the rainy season and for grazing thereafter, may be treated with sparsely (widely) spaced contour trenches, and seeding of grasses and suitable shrubs thereon. Leguminous plants like *Stylosanthes hamata* are recommended, along with Moringa and Sesbania. Other tree species may be selected in consultation with the respective farmers. Similarly, stone or earthen farm bunds (with soil excavated by trenches on the upper side) may be taken up wherever slopes and soil depth permit.

2. Soil conservation in the farmlands (middle and lower reaches)

Several farmers have constructed earthen and stone bunds in or around their farmlands for soil conservation several years ago. The practice still continues, as a few farmers in the village Morve were seen constructing stone bunds during the field survey, albeit along with land levelling, around their farmland. Constructing farm bunds, along with compartment bunds, is a proven method of effective soil conservation, and when done using stones, it removes the need for providing a spillway to drain surplus runoff.

It is recommended that farm bunding with compartment bunds be systematically implemented across all farmlands in the middle and lower reaches of the catchment. This measure will aid in enhancing soil moisture retention, reducing runoff velocity, and improving the overall productivity and resilience of agricultural lands. In addition, existing bunds that are eroded, broken, or too low should be repaired and, where necessary, raised in height to ensure their effectiveness in current climatic and land use conditions.

All newly constructed and repaired bunds must be properly stabilized. This includes the seeding of grasses and hardy shrubs along the bund slopes to prevent erosion, as well as the plantation of suitable tree species along the bund lines wherever feasible. These vegetative measures not only protect the bunds from degradation but also contribute to increased biodiversity, improved microclimate, and potential additional income from trees in the long term.

It is a common experience that farmers have a resistance to the plantation of trees on the farm bunds, thinking that the shade effect would reduce their crop production. It is necessary to hold a systematic dialogue with the farmers about the usefulness of the bund plantation along with its economic returns. Initial discussions with a few farmers (e.g. in village Morve during field visit, and in other villages during FGDs) showed their understanding and willingness.

3. Water augmentation strategy

In the entire catchment, a very limited scope could be found for taking up new runoff harvesting or water augmentation structures. The government has already constructed several earth fill dams (earthen gully plugs and nalla bunds), and check weirs (masonry, concrete and Kolhapur type weirs) across several mid-sized streams in the lower reaches. Most suitable (or technically feasible and advisable) sites have already been selected by the government to put up these structures, thus leaving negligible scope for taking up any new structures. It was also noted that most of these structures serve as storage structures and not as recharge structure. The presence of hard basaltic rock in the stream beds, either exposed or just underneath, prevents any downward movement or infiltration of water. Further, such runoff harvesting structures in the streams will have a very limited use to the farmers or other water users like livestock, due to their location and limited capacity. **Given these findings, no new structures are recommended.**

1) There are a few already existing gully control structures (like loose boulder gully plugs, earthen gully plugs or nalla bunds) in the upper and middle reaches (mostly done by the government in the past. These may be repaired or renovated in order to increase their functionality and utility. Such work may include de-silting, spillway repair, bank protection by stone pitching or grass seeding.

2) The check weirs (masonry, concrete and Kolhapur type weirs) in the middle and lower reaches are in different states of repairs or disuse. Appropriate repairs and renovation of these structures may be taken up with a view to increase its utility.
3) Some of these structures serve as a water source for washing clothes of the local households. It is recommended to provide washing platforms, increasing their convenience and safety. Location and design of such platforms should be decided in consultation with the local women who are its main users.
4) Several exotic buyers of land have put up fences (and barriers) not on their plots, but also the adjacent common spaces like paths/ tracks/ roads and nallas around their plots. Such encroachment, in legal and ethical parlance, has badly affected the access of the local population, especially women, to the streams and grazing land. It is recommended to hold dialogue between such encroachers and the local bodies (Gram Panchayats) with a view to remove encroachment, provide paths or access, and thereby, restore the riparian rights of the local community.
5) Protection of water courses: Plantation of bamboo along all water courses in the lower reaches (wherever the soil depth permits) and along the submergence area contour water storage bodies will prevent siltation, and thereby, preserve these important water resources. It should be planned in consultation with the adjacent land owners and the concerned riparian users.

4. Groundwater recharge

Our study of open wells in the middle reaches showed sporadic presence of multi-layer aquifers, but the discussions with the farmers in the lower reaches (villages Morve and Jadhav wadi) revealed that these wells used to be perennial in the past, but now yield water only up to winter. There is a scope of increasing the yield of these wells and lengthening the period of water availability by a few months by increasing the recharge.

It is recommended to carry out intensive soil conservation work in form of farm bunding in the lower reaches, say, between 600 m MSL to 700 m MSL. These bunds should be strengthened by grass seeding and plantation of shrubs and trees. Also, it is important to improve the water holding capacity of the soils by adding biomass into the soil (mulching, green manure, application of silt/compost/cow dung, etc.).

5. Water use prioritization and demand management

The strategy should be demand management and not supply augmentation. Drinking and domestic water use, water for ecosystems, water for livelihoods (farming, livestock, artisanary work etc) should have higher order priority than recreational or commercial uses. Only after meeting these basic needs, water should be allowed to be used for recreational and commercial purposes. Through appropriate cropping choices and agronomical practices, the efforts should be to reduce the water footprint.

All tourism establishments—including resorts, guesthouses, and restaurants—should be encouraged or mandated to adopt water conservation practices. This may include rainwater harvesting, wastewater recycling, and the use of water-efficient fixtures and systems to ensure long-term sustainability of water use in the catchment.

6. Farming systems

As discussed earlier, farming systems are central to achieving sustainable land and water management in the Shilimb watershed. Despite the growing prominence of tourism-based enterprises, the following components will continue to define sustainable farming systems in the region.

- The topography and the land forms are suited for livestock and tree-based farming systems rather than seasonal crop cultivation. Hence, the watershed development strategy should strongly favour such land use and farming systems. The livestock component is discussed in the next section.
- Forest cover or woodlands in the upper reaches. These should sustain with limited grazing (preferably rotational grazing) and periodic harvesting of grasses (esp. selective cutting of Andropogon-like species a little after flowering, say around Diwali).
- Grassland with trees on sloping lands in the middle reaches. In case, the soil depths permit, these lands could also be utilised for rainfed crops like upland paddy (if those traditional variety seeds are still available), millets likeFinger millet (nachni) and Foxtail millet (rala), pigeon pea, etc. Appropriate crops and varieties should be determined in consultation with the farmers. Existing shrubs and trees like karonda, custard apple may be promoted (conserved, or propagated through direct seeding in and around any bushy growth). The grazing management should depend on the carrying capacity and demand (number of small and large ruminants).
- Tree-based farming on fallow lands in the lower reaches. The sloping lands in the lower reaches should be developed with contour trenching and bunding, along with plantation

of traditional tree species like *mahua*, custard apple, mango, tamarind, wood apple, bel, etc chosen in consultation with the farmers.

- Seasonal crop cultivation in the lower reaches: Agriculture is presently dominated with seasonal crops like paddy in rainy season, followed by wheat in winter. Since rice is a popular staple, paddy cultivation will continue. It may be supplemented with sesame and pigeon pea on the periphery or adjacent upland. Green gram and black gram should be encouraged. More importantly, wheat in rabi season could be gradually replaced by Bengal gram and suitable oilseed crop like safflower.

7. Livestock promotion

A separate section is written on livestock because of the latter's significance in the rural economy of Shilimb watershed. In view of the growing tourism and resultant demand for milk, eggs, and meat products, the importance of livestock will increase manyfold. Given the natural suitability of the terrain and land-water situation for rearing small and large ruminants, livestock promotion assumes an important place in the development priorities of the region.

It is necessary to provide utmost importance to the development of grasslands with trees, with priority to fodder trees and shrub species (esp. fodder for goats). Free ranching may not be an immediately feasible alternative given changing land ownership and resultant access issues (due to erecting fence by exotic land owners), unless riparian rights and rights to common and private grazing lands are restored in favour of the livestock and their herders. Yet, community-led grassland utilisation solutions should be developed/ evolved in consultation with the herders and the exotic land-owners. In this direction, the following pragmatic actions are recommended.

Rotational grazing practices: The grasslands in the upper reaches, irrespective of their ownership, may be divided into zones of about 10-25 ha, depending upon the topography (ridge-to-ridge micro-watershed zones). The already demarcated 32 micro-watersheds may be treated as the management units for the purpose, with each micro-watershed divided into 3-10 rotational grazing zones, based on the demand (livestock population) and supply (geographic area) situation.

Buffaloes: Several farming families are rearing buffaloes in an extensive manner. Buffalo milk, butter and ghee will be in high demand in the new tourism space. A little support in feed and fodder management and animal health-care will help increase the farmers' income. A semi-decentralised procurement and distribution system run through FPOs or SHGs will provide a fillip to this activity in a big way. Cows may be reared for any fancy purpose, but with limited financial success.

Goat is the key: The area is suitable for goat rearing. Local breeds (including a close cousin, Sangamneri goat) may be promoted in small herds of 6-20 animals per family. It could be an excellent economic opportunity for smallholders and the landless *Thakar* and *Katkari* families.

Local poultry: Chicken and eggs will be in high demand due to growing tourism. The normal practice is to get the supply from commercial poultry farms rearing exotic breeds. The local farmers should be encouraged (and more precisely, trained) to rear local poultry birds in the backyard (a manner close to free-ranching on a tiny scale).

Promotion of local breeds: It goes without saying that the project authorities should not get enamoured with any fancy breeds from across the continent. Local breeds are generally well adapted to the local climate and resource situation, and therefore, should be preferred.

Important caveat: One must avoid the populist approach of distributing animals (chicks, birds, goats, cows, buffaloes, etc) and use it as an achievement indicator. Instead, it should focus on developing systems that enhance productivity, reduce risk and promote green food principle.

8. Institutional arrangements

It is important to have an institution for the Shilimb watershed as a whole, built from below (from micro watershed/village scales in a nested institutional framework). This could be a multi-stakeholder platform. Along with this, efforts should be made to build consensus around water use, entitlements, cropping patterns, agronomical practices, recycle and reuse etc. In the absence of such rules, all the augmented water resources will be grabbed by outsiders (real estate owners, hotels and resorts, etc). Water use in resorts, hotels and other commercial ventures should be monitored, and the data should be made available to the public.